MOBILE ELECTRONIC THREE-DIMENSIONAL COMPASS

FIELD OF THE INVENTION

The invention relates to a mobile electronic system comprising means which realize the function of a compass and to components of such a system. The invention relates equally to a method for a mobile electronic system.

BACKGROUND OF THE INVENTION

It is known from the state of the art to provide mobile electronic systems with a two dimensional compass. Such a mobile electronic systems may be included for instance in a communication device like a mobile phone.

In German patent application DE 198 37 568 A1, it is proposed to provide a Personal Digital Assistant (PDA) with a Global Positioning System (GPS) receiver, a mobile communication unit and a compass. The compass is used for determining the current orientation of the PDA, which is required for realizing navigation functions in the PDA.

In British patent application GB 2 298 539 A, it is equally proposed to provide a hand held device containing a GPS receiver with a compass. A displayed information relating to the current environment, e.g. a map, is rotated in accordance with the respective orientation of the device.

Further, it is proposed in international application
WO 01/88687 A2 to access context information with a user
equipment, e.g. a mobile phone. The context information
is downloaded from a network based on a location service.
Then, the orientation of the user equipment is determined
using a compass in the user equipment. Once the
orientation is known, a visual user interface is
generated at the user equipment for displaying the
downloaded context information. In order to select a
virtual object displayed in the visual user interface,
the user can point to the respective object by orienting
the user equipment. During the movement of the user
equipment, the displayed virtual objects move accordingly
in front of the user.

A mobile electronic system may also comprise an Inertial
Navigation Systems (INS), which INS can be used for
determining the position of the mobile electronic system.
In such a system, it is essential that provided heading
information remains accurate along time, since even small
errors in the computed orientation cause significant
errors to the position estimate. Traditionally, IN
Systems utilize gyro-compasses to ensure an accurate
heading. Gyro-compasses, however, have several
disadvantages. They constitute quite expensive components
due to their complicated electronics. Moreover, they are
physically large sensors and can thus not be implemented
in small modules. The use of a conventional 3-axis gyro-
compass in a small INS is not feasible at all, since it
requires even more complex electronics and its power
consumption is much higher. As a result, it is more
expensive and it also requires more space. A 3-axis
operation, however, is essential for an accurate INS.

SUMMARY OF THE INVENTION

It is an object of the invention to expand and enhance
the usability of a mobile electronic system.

This object is reached according to the invention with a
mobile electronic system, which comprises output means
enabling a presentation of information to a user of the
mobile electronic system. The proposed mobile electronic
system further comprises a 3D (three-dimensional)
magnetometer performing magnetic measurements in three
dimensions and providing data indicative of the current
posture of the mobile electronic system based on these
measurements. The 3D magnetometer thus realizes the
functions of a 3-dimensional compass. Finally, the
proposed mobile electronic system comprises processing
means processing the data provided by the 3D magnetometer
for enabling a posture related presentation of
information via the output means.

The mobile electronic system may be a single unit or be
composed of several units. It may be comprised, for
example, completely in a user equipment like a mobile
communication device. Alternatively, the mobile
electronic system may comprise for example a user
equipment including the output means, while at least the
3D magnetometer is included in a separate, complementary
unit which can be connected to the user equipment. In the
latter case, the connection should be rigid so that the
posture of the complementary unit with the 3D
magnetometer corresponds always to the posture of the
user equipment. The processing means can then be included

in either of the two units or be distributed to the two units. The unit comprising the output means may be for example a mobile phone and the complementary unit comprising the 3D magnetometer a functional cover for the mobile phone.

The object of the invention is equally reached with a corresponding complementary unit and with a corresponding user equipment comprising either the part of the proposed mobile electronic system not comprised by a complementary unit or the entire proposed mobile electronic system.

The object of the invention is further reached with a corresponding method for a mobile electronic system. The method comprises in a first step performing magnetic measurements in three dimensions in the mobile electronic system. The method comprises moreover determining data indicative of the current posture of the mobile electronic system based on the performed magnetic measurements. Finally, the proposed method comprises processing this data for enabling a posture related presentation of information to a user of the mobile electronic system.

The invention is based on the consideration that a 3D magnetometer is able to sense not only the orientation of a device in which it is included or to which it is attached in a horizontal plane, like a 2D compass, but also its current inclination. This additional data can be employed for a variety of new or enhanced functions of a mobile electronic system. It can be used for example to enhance the presentation of information and/or to select a mode of presentation depending on the current posture

of the mobile electronic device. A 3D magnetometer can further be used as main source for heading information in an inertial navigation system, since it is smaller and less expensive than a gyro-compass.

Preferred embodiments of the invention become apparent from the dependent claims.

In a preferred embodiment of the invention, the presented information comprises compass information.

In another preferred embodiment of the invention, different modes of presentation are selected depending on the posture of the mobile electronic system. In case the output means comprise a display and the mobile electronic system is held basically horizontally, the display and functioning can resemble e.g. to a traditional compass. When the mobile electronic system is held basically vertically, in contrast, the presentation of information may be switched to some other mode.

In another preferred embodiment of the invention, the output means comprise a 3D display for a presentation of compass information, e.g. a presentation of a floating compass. This enables a new user experience compared to a 2D electrical compass, which cannot even be used in free posture.

In another preferred embodiment of the invention, the system comprises additional sensor means, which provide further measurement data. These further measurement data can be employed by the processing means in addition for enabling the posture related presentation of information

via the output means. The additional measurement data
allow the processing means to adjust the functionality of
the system to the environment and/or to a user profile.
For example, data on the posture and the characteristics
of the movements of the mobile electronic system can be
used to change the functionality. The adjustment of the
functionality may comprise for example an adjustment of
the presentation of information via the output means
and/or an adjustment of a filtering of signals provided
by the 3D magnetometer.

The additional sensor means may comprise for example a 2D
or 3D linear accelerometer measuring the acceleration of
the mobile electronic system in two or three dimensions,
respectively, or a 3D angular accelerometer measuring the
angular acceleration of the mobile electronic system in
three dimensions.

Since a magnetic compass is subjected to unpredictable
disturbances, a 3D angular accelerometer can be used to
verify whether sudden changes of direction indicated by
the 3D magnetometer actually occurred or whether there
was only a temporary disruption. This enables a
compensation of random magnetic disturbances. From an
implementation point of view, angular accelerometers have
the advantage that they do not require any dedicated
electronics and that they can be read with the same
electronics as linear accelerometers. Angular
accelerometers are also inexpensive and smaller than
gyro-compasses.

In case a 3D angular accelerometer is used as additional
sensor means, the 3D magnetometer may provide first data

indicating a current heading of the mobile electronic
system, while the 3D angular accelerometer provides
second data indicating a current heading of the mobile
electronic system. Moreover, the processing means may
comprise a complementary filter combining the first and
second data, in order to obtain a particularly reliable
information on the current heading of the mobile
electronic system.

A combination of a 3D magnetometer and a 3D angular
accelerometer is of particular advantage for an INS
realized in the mobile electronic system.

It is understood that data provided by the 3D
magnetometer may be used for various applications in the
mobile electronic system.

BRIEF DESCRIPTION OF THE FIGURES

Other objects and features of the present invention will
become apparent from the following detailed description
considered in conjunction with the accompanying drawings,
wherein:

Fig. 1   schematically illustrates a first posture
          dependent display mode employed in a first
          embodiment of the invention;

Fig. 2   schematically illustrate a second posture
          dependent display mode employed as first example
          in the first embodiment of the invention;

Fig. 3   schematically illustrate a second posture
          dependent display mode employed as second example
          in the first embodiment of the invention;

Fig. 4a-d schematically illustrate a simulation of a
        floating compass in a second embodiment of the
        invention;

Fig. 5   is a block diagram of a complementary filter
        employed in a third embodiment of the invention;
        and

Fig. 6   is a block diagram of a complementary filter in
        one compass plane that is based on two axis of a
        magnetometer and on an angular accelerometer.

DETAILED DESCRIPTION OF THE INVENTION

In a first embodiment of the invention illustrated in
figures 1 to 3, a mobile phone 10 can be employed as a
two-dimensional compass with two different presentation
modes. The mobile phone 10 comprises buttons 11, a
display 12, a 3D magnetometer, a 3D accelerometer and
processing means.

The 3D magnetometer constantly performs magnetic
measurements in all three dimensions. The measurement
results, which constitute an information on the current
posture of the mobile phone 10, are provided to the
processing means. Moreover, the 3D accelerometer
constantly performs acceleration measurements in all
three dimensions. Also these measurement results, which
allow a to draw conclusions as to the current velocity of
the mobile phone, are provided to the processing means.

As long as the measurement results by the 3D
accelerometer indicate that the mobile phone is only
moved slowly, a fast acting filtering software is
activated in the processing means for filtering the

measurement results provided by the 3D magnetometer. The
fast acting filtering software filters the measurement
results with an integration period of about 1 to 3
seconds, which removes e.g. the influence of hand
vibrations, of by-passing cars and of disturbances in the
magnetic fields of the earth.

In case the measurement results by the 3D accelerometer
indicate, in contrast, that the mobile phone is moved
with an increased velocity, a slow filtering software is
activated in the processing means for filtering the
measurement results provided by the 3D magnetometer. The
slow filtering software filters the measurement results
with an integration period of about 5 to 10 seconds. The
slow filtering is activated for instance in case the
compass function is to be used while the user is driving
in an urban city environment, in order to filter
temporary fluctuations in the magnetic field due to
bypassing trams, buses, buildings, metal constructions,
etc.

The filtered measurement results of the 3D magnetometer
are then evaluated by the processing means for presenting
compass information on the display 12 of the mobile phone
10.

When the magnetic measurements indicate that the phone 10
is positioned basically horizontally, which may e.g. be
the case when a user of the phone 10 is walking, a first
mode of presentation is selected by the processing means.
In the first mode of presentation, the display 12 and the
functioning resembles a traditional compass.

For this first mode of presentation, the processing means
determine the direction in the horizontal plane to which
the top of the mobile phone 10 is oriented based on the
provided measurement results. The orientation information
contained in the filtered signal is then reflected by an
arrow 13 in a circle 14 on the display 12 of the mobile
phone 10, as shown in figure 1. The circle 14 with the
arrow 13 represent a conventional compass. Accordingly,
the arrow 13 is always oriented such that it points to
the North. Alternatively, any other predetermined
direction could be indicated based on the filtered
signals. The fast acting filtering, which is activated
when the user is walking, allows the user to find North
without unnecessary delays.

When the magnetic measurements indicate, in contrast,
that the degree of an inclination of the mobile phone
exceeds a predetermined value, which may e.g. be the case
when a person is tilting the phone or when it is kept in
a car stand, a second mode of presentation is selected.

For the second mode of presentation, the processing means
determine the orientation of the back of the tilted
mobile phone based on the filtered magnetic measurement
results. The presentation of the determined compass
information differs moreover from the presentation in the
first mode of presentation, since a simulation of a
conventional compass as in the first mode of presentation
is not appropriate with a tilted phone.

Two possibilities for the second mode of presentation are
illustrated in figures 2 and 3.

In the first possibility illustrated in figure 2, the
presentation on the display 12 resembles a "marine
compass". In a first row, the current orientation of the
phone is indicated by the points of the compass North
"N", East "E", South "S" and West "W", while in a second
row, the current orientation of the phone is indicated by
corresponding degrees "90", "180", "270" and "360". In
the situation depicted in figure 2, the user of the phone
faces North-West or 315°, since the center of the first
row lies between an indicated "N" and an indicated "W",
and the center of the second row lies between indicated
"360" and "270" degrees.

The second possibility for the second mode of
presentation illustrated in figure 3 is provided in order
to enable a user of a mobile phone 10 to easily keep a
preset target direction. The direction may be entered via
the buttons 11 of the mobile phone 10. The desired
direction can be selected in particular using the points
of the compass or a corresponding indication in degrees.

The direction information contained in the filtered
magnetic measurement results is then reflected by a
simple arrow pointing in the desired direction on the
display.

Figure 3 presents the view of a driver of a car who is
using the mobile phone 10 with the second possibility for
the second mode of presentation. The mobile phone 10 is
fixed in a car stand, which is connected to the dashboard
on the right hand side of the steering wheel of the car.
In the presented example, the arrow 15 shown on the

display 12 of the mobile phone 10 indicates that the
desired direction is straight ahead.

With the second possibility for the second mode of
presentation, thus a simplified navigation system is
provided. It may be used for example when driving in an
urban environment towards an airport, which is lying in a
known direction. The slow filtering, which is activated
when the user is driving, ensures that most magnetic
disturbances are not visible in the presentation of the
compass information.

In a second embodiment of the invention, a mobile phone
can be employed for simulating a floating three-
dimensional compass, e.g. a floating navy compass. Like
the mobile phone of the first embodiment, the mobile
phone of the second embodiment comprises buttons, a
display, a 3D magnetometer, a 3D accelerometer and
processing means. In the second embodiment, however, the
display is a 3D display.

The 3D magnetometer constantly performs magnetic
measurements in all three dimensions, which provide an
information on the current posture of the mobile phone.
The 3D accelerometer further measures the accelerations
of the mobile phone in all three dimensions.

The measurement results of the 3D magnetometer and the 3D
accelerometer are used by the processing means for
presenting the floating compass on the display of the
mobile phone. More specifically, the measurement results
provided by the 3D accelerometer are used by the
processing means for filtering the measurement results

provided by the 3D magnetometer with a delay, similarly
as described for the first embodiment. Then, the
processing means show a 3D compass on the 3D display, of
which the orientation corresponds to the posture
information contained in the filtered measurement
results. The compass is represented by the processing
means on the 3D display such that a user can view the
compass from all sides by tilting the mobile phone. Due
to the filtering of the signals, the displayed compass
follows changes of the posture only slowly, resulting in
the particular effect of a virtual floating compass.

Figures 4a-4d schematically illustrate the presentation
of the floating compass on the display 42 of the mobile
phone for various postures of the phone.

The compass is represented as a sphere 43 on the 3D
display 42 of the mobile phone. The top of the sphere 43,
and thus of the virtual compass, is indicated by circles
44. In all four cases illustrated in figures 4a-4d, the
user of the mobile phone is facing South-East (SE). An
arrow 45 indicating the direction which the user faces is
thus labeled "SE". The arrow 45 is always pointing to the
top 44 of the sphere 43. A circle 46 is depicted around
the middle of the sphere 43, all points of the circle
being equidistant to the top 44 of the sphere 43.

Figure 4a shows the display 42 in a first situation, in
which the mobile phone is hold vertically. The top 44 of
the compass is depicted next to the top 47 of the display
42. The arrow 45 indicating South-East is rather short in
the first situation.

Figure 4b shows the display 42 in a second situation in
which, proceeding from the first situation in figure 4a,
the mobile phone is tilted sideways to the right. The
user has exactly the same view on the represented compass
as in figure 4a. That is, the top 44 of the compass is
now depicted next to the upper left corner 48 of the
display 42. The arrow 45 indicating South-East has the
same length as in figure 4a.

Figure 4c shows the display 42 in a third situation, in
which, proceeding from the first situation in figure 4a,
the mobile phone is tilted forward. As a result, the
bottom of the mobile phone is now somewhat closer to the
user than the top of the mobile phone. The represented
compass appears to be rotated towards the user, since the
top 44 of the compass is shifted in direction of the
center of the display 42. The arrow 45 indicating South-
East is slightly longer than in figures 4a and 4b.

Figure 4d shows the display 42 in a fourth situation, in
which the mobile phone is hold horizontally. The user of
the mobile phone has now a top view on the represented
compass. Thus, the top 44 of the compass is depicted in
the center of the visible part of the sphere 43. The
arrow 45 indicating South-East extends throughout the
visible part of the sphere 43. The visible part of the
sphere 43 is now limited by the circle 46 depicted around
the middle of the sphere 43.

The second embodiment of the invention is ideal for
mobile phones having a large color display.

In a third embodiment of the invention, a mobile phone is
employed for realizing an INS. To this end, the mobile
phone comprises a display, a 3D magnetometer, a 3-axis
angular accelerometer and processing means.

Measurement results provided by the 3D magnetometer and
the angular accelerometer are used by the processing
means for presenting the current heading of the user of
the mobile phone on the display. The 3D magnetometer
provides an excellent long term reference for the angular
position of the device. However, magnetometers are
sensitive to external disturbances. The angular
accelerometer on the contrary presents low noise
operation but poor stability. Thus, the combination of
the magnetometer and the angular accelerometer provides
means to perform a measurement with good stability and
good tolerance to external disturbances.

Figure 5 is a block diagram which illustrates the
processing of the signals provided by the 3D magnetometer
and the angular accelerometer. The block diagram
comprises a first block 50 representing the 3-axis
angular accelerometer and a second block 51 representing
the 3D magnetometer. The output of the angular
accelerometer 50 is connected to first filter means 52
and the output of the 3D magnetometer 51 is connected to
second filter means 53. The outputs of the filter means
52, 53 are connected to a summing point 54. The filter
means 52, 53 and the summing point 54, which form a
complementary filter, are part of the processing means of
the mobile phone.

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The angular accelerometer 50 measures angular
accelerations of the mobile phone in any direction
proceeding from a point of time at which the heading was
known until a new point of time t. Based on the measured
movements and on the last known heading, the angular
accelerometer then estimates the new heading at point of
time t and provides a corresponding first heading signal.
This first heading signal comprises the true heading $s(t)$
at point of time t and a noise component $n_1(t)$, which
takes account of errors in the angular measurements.

At the same point of time t, the 3D magnetometer 51
performs in addition magnetic measurements, in order to
determine the current posture of the mobile phone. Based
on the magnetic measurements, the 3D magnetometer 51 then
estimates as well the new heading of the mobile phone at
point of time t and provides a corresponding second
heading signal. This second heading signal comprises
equally the true heading $s(t)$ at point of time t and a
noise component $n_2(t)$, which takes account of errors in
the magnetic measurements.

As a result, two redundant measurements of the same
signal are available. These two measurements can now be
combined in a way that the measurement error is
minimized. This is achieved with the complementary
filter, to which the two heading signals are provided.

The first heading signal is subjected by the first filter
means 52 to a filtering function which has a transfer
function $G(s)$. Moreover, the result of the function $G(s)$
is subtracted from 1. The second heading signal is only

subjected by the second filter means 53 to a filtering
with a transfer function G(s). The output of the filter
means 52, 53 is then summed at the summing point 54,
resulting in the sum x(t). Such a complementary filtering
allows to filter the noise without distorting the signal.

The signal output by the summing point 54 thus reflects
very closely the true heading of the mobile phone at
point of time t, and a corresponding information can be
presented on the display of the mobile phone.

Figure 6 presents a more concrete implementation of a
complementary filtering based on the use of an angular
accelerometer for compensating magnetic field
disturbances in the signals of a magnetometer.
Figure 6 is more specifically a block diagram of a
complementary filter for one compass plane that is based
on a two axis magnetometer and an angular accelerometer.
A similar implementation is required for all three
directions.

The block diagram of figure 6 comprises two blocks 61, 62
representing measurement values m_x, m_y of a 3D
magnetometer in a first direction x and a second
direction y, respectively. The two blocks 61, 62 are
connected to a block 63 representing compass functions.
The output of this block 63 is connected on the one hand
via a block representing a derivator 64 to a first
summing point 65 and on the other hand to a second
summing point 66. The block diagram moreover comprises a

block 67 representing measurement values $\dot{\theta}_{xy}$ of an angular

accelerometer. This block 67 is connected to an

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integrator 68 and further to the first summing point 65.
The output of the first summing point 65 is connected to
a block representing an adaptive filter 69. The output of
block 69 is connected as well to the second summing point
66. A dashed line separates the sensor related blocks 61,
62 and 67 on the left hand side from the other, digital
signal processing related blocks on the right hand side.

The compass signal θ_{xy} that is calculated in block 63 from
the magnetometer values m_x, m_y is differentiated in the
derivator 64 with respect to time in order to remove the
constant field value. The resulting value indicates the
angular velocity based on the magnetic field, but
includes high frequency disturbances. The corresponding
angular acceleration signal $\dot{\theta}_{xy}$ is integrated in the
integrator 68. The resulting value indicates the true
angular velocity based on the acceleration of the mobile
phone, but comprises a low frequency drift. The time
constants of derivator 64 and integrator 68 are matched.

The two signals $\dot{\theta}_{xy}$ output by the derivator 64 and the
integrator 68 are compared by means of the summing point
65 in order to separate the disturbances and the low
frequency drift of the true angular velocity. The summing
point 65 subtracts more specifically the value obtained
from the derivator 64 from the value obtained from the
integrator 68. The signal is then passed through the
adaptive filter 65. The adaptive filter applies a high-
pass filtering on the received signal in order to
separate the disturbances of the signal. The disturbances
are further integrated in the adaptive filter 65 in order

to obtain an estimate of the angular error of the device
for the inertial navigation purposes.

The high-pass filtered estimate of the angular error is
then subtracted by the second summing point 66 from the
compass heading information θ_{xy} including disturbances,
which is output by block 63. The output of the second
summing point 66 is thus a corrected compass heading $\theta_{xy,corr}$
for one compass plane.

The system of figure 6 can be further improved by using
adaptive filters, such as Kalman filters, for the error
signal processing.

It is to be noted that the described embodiments
constitute only selected ones of a variety of possible
embodiments of the invention.